FEASIBILITY STUDY FOR THE GEORGIA DEPARTMENT OF TRANSPORTATION TO DETERMINE THE ECONOMIC AND OPERATIONAL BENEFITS OF UTILIZING UNMANNED AERIAL VEHICLES (UAVS)

SPECIAL RESEARCH STUDY PROPOSAL

Project Director:
Adeel Khalid, Ph.D.,
(Phone) 678-915-7241
akhalid2@spsu.edu

Project Co-Directors:
Sung-Hee (Sonny) Kim, Ph.D., P.E.,
(Phone) 678-915-5491
Skim4@spsu.edu

Chih-Cheng Hung, Ph.D.,
(Phone) 678-915-3574
chung@spsu.edu

Southern Polytechnic Applied Research Corporation
1100 South Marietta Parkway
Marietta, GA 30060

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Feasibility Study for the Georgia Department of Transportation to Determine the Economic and Operational Benefits of Utilizing Unmanned Aerial Vehicles (UAVs)

INTRODUCTION

Unmanned Aerial Vehicles (UAVs) are used for a variety of military and civilian applications. These include but are not limited to aerial photography, traffic monitoring, and emergency response management. UAVs have become smaller, more capable and less expensive because of the continuously improving technology and their growing use. Currently available UAVs are small enough that they can be transported in small vehicles and launched from a roadside without the need of a runway. At the same time, they are capable enough to carry sensors, flight computers, cameras and other equipment to provide aerial information at low cost. These aircraft can be programmed to fly autonomously.

This technology has application potential for traffic and transportation organizations like Georgia Department of Transportation (GDOT). The State of Georgia is interested in becoming one of the six Federal Aviation Administration (FAA) regional UAV test sites. It is prudent that a detailed feasibility and viability study is performed for UAV integration in the current and forecasted traffic patterns in Georgia. This study will help determine the applicability of UAVs for numerous other uses in GDOT and other sectors.

This opportunity will allow for exploration of the benefits and capabilities of UAVs for Department and its various division operations as it relates to safety, efficiency and capacity. This feasibility study will analyze the operations of each Division within the Department to determine the need for a UAV, the user requirements for the UAV and a cost benefit analysis to determine if UAV utilization is both operationally feasible and economically viable. Data collection regarding existing and ongoing research for each UAV application will also be performed.

OBJECTIVES

The objective of this study is to provide a starting point for the development and flight testing of a UAV(s) for Departmental applications as well as create an opportunity for Georgia to provide pertinent UAV data to the FAA to help guide policy decision making.

This endeavor will have a two-fold benefit.

1. Provide the Georgia Department of Transportation with a technology to advance the safety, efficiency and capacity of the state transportation system, and
2. Promote research and flight data collection for FAA to use in developing policies and certification requirements for UAV integration in the National Airspace

This research will also help to determine the potential uses for UAVs across all GDOT divisions, detail the user requirements and present a cost benefit analysis for each proposed UAV application.

RELATED WORK

A research study is underway at Southern Polytechnic State University (SPSU) to design, build, and fly an Autonomous Aerial Patrol and Surveillance System (APSS). The goal of this project is to create a safe autonomous UAV system that is equipped with visual, infrared, and heat seeking cameras. The vehicle will be operated by the campus police department. Currently, in the case of an emergency call, a police dispatcher is sent to the scene. It may take several minutes for the emergency crew to arrive. By the time the officer gets to the location, often times the emergency has either escalated, or it no longer exists. In this project, we are creating an unmanned UAV system that can be sent to the scene of emergency, anywhere on campus, in the matters of seconds. The onboard cameras will send live video feed to the base station where the officers will be able to make an instant judgment about the status of the situation and take appropriate actions. The system will be agile enough to follow a person of interest or vehicle on campus. The system will also be equipped with night vision cameras, so it can be used after dark.

The autonomous feature of the vehicle will eliminate the need to actively control the vehicle at all times. The operator will have the campus map on a mobile device e.g. iPad. The operator will be able to point on the map, which will send a command to the vehicle to fly to the corresponding location on the map and hover or loiter there to send live video feedback. The onboard GPS system will help the onboard computer to determine the current and the next location of the vehicle at all times. The current location will also be displayed, in addition to the live video feedback, on the monitor screens at the base station. The intention is to create a vehicle to have 90 minute endurance so it could be used for long operations. The system can also be used for every day surveillance, patrol, and safety operations. The use of the autonomous UAV is expected to save time and money for the campus police department. The ground testing of APSS rover is shown in Figure 1. The mission planner for the control and monitoring of the vehicle is shown in Figure 2.

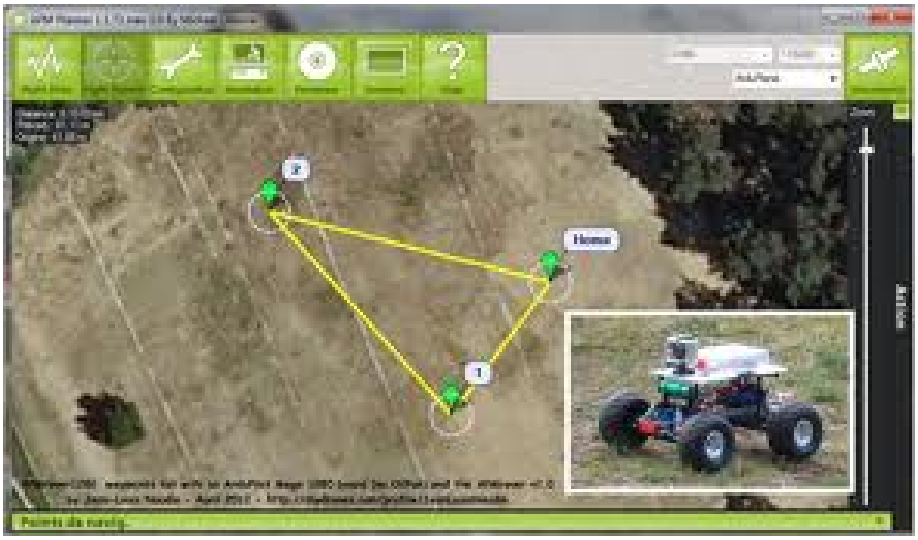

Figure 1: Ground Testing of APSS

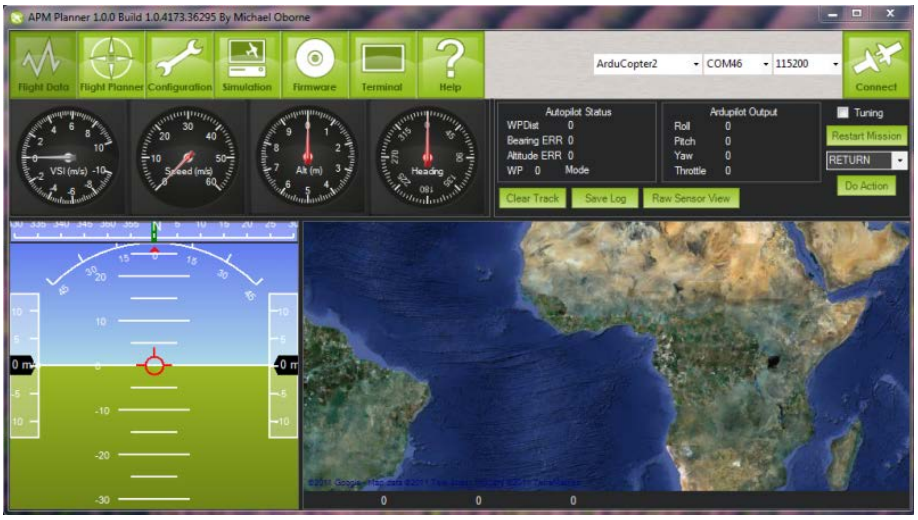

Figure 2: Mission Planner Interface for the APSS

The aerial testing rotorcraft based platform is shown in Figure 3. Some aerial shots obtained at SPSU from preliminary tests of APSS flight vehicle are shown in Figure 4.

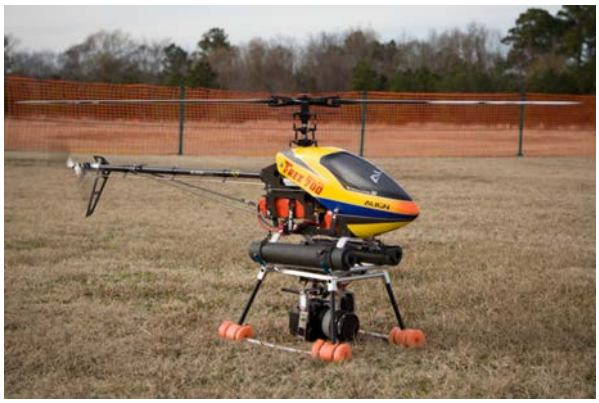

Figure 3: Aerial Testing of APSS

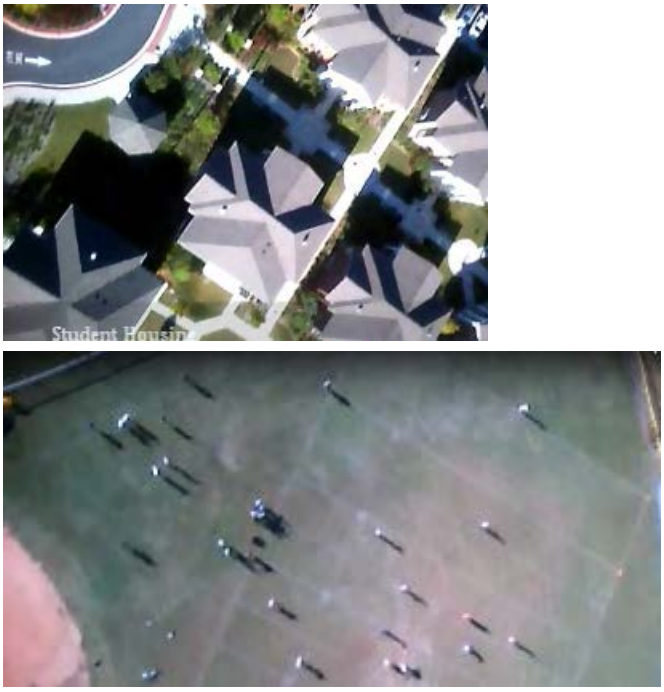

Figure 4: Aerial shots obtained on SPSU campus

When the APSS project is complete, and a safe and reliable waypoint to waypoint navigation enabled flying vehicle has been developed, it can be applied to a number of other projects which include traffic monitoring and aerial photography on a wider scale.

APPLICATION

Linking the traditionally collected infrastructure attributes with geographical coordinates is not easy for visual displays on computer maps. The feasibility study of UAV will be applied to the use of geographical information system (GIS) to enhance integration of highway asset management systems, the Pavement Management System (PMS). From this the research team will conduct pavement performance study for a test section with

the UAV. The image of pavement deteriorations such as pavement cracking and rutting will be captured and analyzed with image processing technique to analyze the existing pavement conditions required to update the PMS system.

The remotely-sensed imaging system is a useful tool for many applications including the surveillance and monitoring pavement condition. Success of the imaging system depends on accurate and robust information extraction through digital image processing and analysis on images taken by the system. To analyze the highway pavement conditions, multispectral and hyeprspectral imaging technology would be an appropriate measurement of object properties (i.e. pavement conditions) on the road surface using data acquired from aircraft or unmanned aerial vehicles. Multispectral and hyperspectral technology captures image data at specific frequencies across the electromagnetic spectrum. While multispectral images have been heavily used in remote sensing in the past few decades, hyperspectral imaging which provides more detailed information at many wavelengths will become promising for future applications. Although the increased dimensionality of hyperspectral data greatly enhances the data information content, it provides a challenge to conventional techniques for analyzing higher dimensional data. Currently, many airborne hyperspectral sensors are available in the commercial market. As hyperspectral imaging develops into one of the core technologies for monitoring, we will explore the feasibility of taking hyeprspectral images of the highway in Georgia and developing image processing algorithms as analytical tools to interpret the road pavement conditions.

OTHER APPLICATIONS OF PROPOSED UAV SYSTEM

Several other applications of the UAVs can be examined per request by the GDOT. Following is a list of potential uses of a successful UAV system:

- LIDAR scanning of existing pavement
- Inspection of bridge infrastructure
- Aerial photography
- Accident reporting and management
- Traffic monitoring
- Roadway inventory
- Emergency response management
- Police operations – emergency response, hot pursuits
- Farming – surveying of crops, spraying

- Search and rescue operations – missing persons
- Advertisement & Surveillance of small businesses (parking lots, garages, hangars, warehouses)
- Inspection of gas pipeline corridors
- Building, road, runway inspection – fly over roads to look for damage that needs to be repaired
- Traffic inspection
- News helicopters
- Delivery of payloads (documents, tools, supplies, newspaper)
- Roofing companies - look for damaged roofs
- Developing archives of aerial videos of historic sites, national parks, bike trails, hiking trails, parks, historic villages, national forests, camp grounds, amusement parks, tourist attractions, etc.
- Aerial views of games (football, baseball etc.)
- Aerial views of motocross racing, NASCAR, horse racing, bicycle races, athletics.

WORK PLAN

To achieve the objective of this study, the proposed research is divided into the eight tasks discussed in this section. The estimated project completion schedule is 12 months, and is shown under Work Plan Schedule.

Task 1: Literature Review

The available literature will be reviewed to gain insight on current work regarding evaluation UAV use in transportation, traffic management, and real time traffic control. There are many instances where UAV utilization research is being performed for transportation specific scenarios. For example, the Utah Department of Transportation is investigating the uses of UAV aerial photography to improve UDOT GIS databases with high resolution photographs of ongoing and recent highway construction. The state of Washington has studied the capabilities of UAVs to use as an avalanche control tool, and the Florida Department of Transportation has researched the feasibility of using surveillance video from UAVs for traffic control and incident management.

Task 2: Review of User Requirements

User requirements will be gathered based on the current needs of the GDOT and its divisions. A requirements database will be established which will serve as

basis for UAV development. A brief review of each division of GDOT operation and mission will be performed with an in-depth analysis of those divisions and offices that have the potential to benefit from UAVs.

Task 3: Primary and Secondary Mission Definition

After the requirements have been defined, a mission profile will be developed to determine the flight path, endurance, takeoff, and landing, and range specifications.

Task 4: Size, Shape, Flight Characteristics and Performance Determination of UAV

In this step, the UAV size, shape, configuration (fixed wing or rotorcraft), maneuverability, range, endurance, payload capacity, and other equipment needs will be determined. Information from existing and ongoing UAV studies will be gathered for each proposed UAV application and will be included as part of this study.

Task 5: Pavement Survey, Image Processing, and Economic Analysis

Once the requirements and essential utility are fully determined, an estimated cost will be developed for UAV design, construction, maintenance, and operation. This cost will be evaluated against the potential for performance enhancement and cost savings to the Department, and will then be developed into a cost benefit analysis report. Each identified division or office will have its own cost benefit analysis report.

Task 6: Preliminary Design, Development, and Testing of UAV

Pavement Survey, image processing, and economic analysis will be conducted on a selected test section. Implementation of the feasibility study will come with the next phase; design, development, research and testing the UAV(s) identified as benefits to the Department.

Task 7: Data Analysis

Data will be gathered from the initial small scale flight tests. This data will give insight into the applicability and feasibility of usage for the designed UAV and larger GDOT projects.

Task 8: Report Findings of this Study

Conclude the study with the preparation of a final research report. Results of the proposed study will be clearly and thoroughly documented in conformance with

the standard research report format. A draft report will be submitted to the GDOT for review two months prior to the end of the contract period. Comments received from the reviewers will be incorporated into the final document.

SIGNIFICANCE OF RESEARCH

Results from this study are expected to provide pavement design professionals with accurate pavement condition survey through UAV surveillance on pavement surface. This research will develop applications and functions to support to improve the current pavement preservation activities.

SUMMARY OF DELIVERABLES

The deliverables of the proposed study are,

Technical memorandum (each task)
Quarterly progress reports
A draft final report
Final report
Presentation/workshop

Quarterly progress reports will be submitted to GDOT and a follow-up meeting with GDOT engineers may be scheduled, if necessary.

The completed feasibility study will give GDOT a platform for implementing UAV(s) to help accomplish the Department's goals in a more efficient and economical way. The study will weigh cost versus the benefits for utilizing UAVs against the traditional methods currently in use. The user requirements defined in this study will also allow for more rapid development of a test UAV if the Department decides to explore the applications further. This study can also be a reference for other states in the nation to use for development of their own UAV applications.

IMPLEMENTATION PLAN

Responsibility for the implementation of the proposed research products rests primarily within the Georgia Department of Transportation. However, the project director and co-directors will provide consultation and design assistance for the GDOT. Meetings and presentations on the research findings will be given to the GDOT personnel.

BUDGET ESTIMATE

The estimated budget of the proposed study is $75,000. An itemized budget summary sheet is submitted separately.

WORK PLAN SCHEDULE

The work plan schedule is prepared by month.

12-month Work Plan

Task	Description	1 - 2	3 - 4	5 - 6	7-8	9-10	11-12
1	Literature Review						
2	Requirements Analysis						
3	Mission Definition						
4	UAV Characteristics and Performance						
5	Economic Analysis						
6	Design, Development, Tests						
7	Data Analysis						
8	Report						

SUPPORT REQUIRED FROM GEORGIA DOT

The following information will be required from GDOT for a detailed study:

1. A brief review of each GDOT Division's operation and mission
2. List of potential benefits to various divisions of GDOT from UAVs
3. Current methods and cost of LIDAR scanning of existing pavement
4. Current methods and cost of inspection of bridge infrastructures
5. Need for aerial photography, location descriptions, resolution requirements, operation requirements
6. Current mechanisms and associated cost for accident reporting and management

7. Methods used for traffic monitoring and associated cost
8. Roadway inventory
9. Current methods and cost of emergency response management

The above data will help the investigators compare the cost of implementing UAV system to augment, extend, and improve several existing GDOT operations.

SUMMARY

The objective of this research is to explore the feasibility of the use of UAVs for GDOT operations. Not only will this study promote advances within state and national surface transportation systems but provide a platform for research as well as flight testing data collection for the FAA to develop accurate UAV integration policies and certification requirements. Both surface and air transportation will be positively impacted by this endeavor.

PROJECT STAFFING AND ADMINISTRATION

Dr. Adeel Khalid will be the Principal Investigator (PI) and Drs. Sung-Hee (Sonny) Kim and Chih-Cheng Chung will be Co-PIs for this research project. Dr. Khalid will be responsible for completing objectives of the study, project tasks implementation, and preparation of the final report.

Adeel Khalid, Ph.D.: Dr. Adeel Khalid is an Assistant Professor of Aerospace Systems Engineering at Southern Polytechnic State University (SPSU) in Marietta, Georgia. His expertise includes Multidisciplinary design and optimization of Aerospace systems. His research interest lies in the design, development, and specifically the applications of Unmanned Aerial Vehicles (UAVs). He has worked as systems engineer at Avidyne Corporation. Avidyne manufactures glass cockpits for general aviation aircraft. Dr. Khalid has expertise in architecture definition, design and development of cockpit avionics. He is experienced in test case scripting, verification and validation of Primary Flight Display (PFD) and Multi-Functional Display (MFD) applications. He is adept in performing requirements definition, analysis, review, management, and documentation using Dynamic Object Oriented Requirements Software (DOORS). As a lead systems engineer, he played an instrumental role in designing, developing, and testing the next generation of Entegra Electronic Flight Instrument System (EFIS). Dr. Khalid received his Ph.D. in Aerospace Engineering from Georgia Institute of Technology. His graduate

research was focused on rotary wing aircraft design and optimization. He holds Master of Science degrees in the discipline of Mechanical Engineering from Michigan State University, as well as Industrial and Aerospace Engineering from Georgia Institute of Technology. He obtained a Bachelor of Science degree in Mechanical Engineering from Ghulam Ishaq Khan Institute. His academic background is notable for a strong emphasis on research and teaching. As a researcher at Georgia Tech, he worked on system design of various aerospace vehicles. His research is focused on system level design optimization and integration of disciplinary analyses. Dr. Khalid has held the positions of adjunct professor at Lahore University of Management Sciences (LUMS) and SPSU. He has also worked as postdoctoral fellow at Georgia Tech.

Sung-Hee (Sonny) Kim, Ph.D., P.E.: Dr. Sung-Hee Kim is an Associate Professor in the Civil and Construction Engineering Department at Southern Polytechnic State University. Dr. Kim has earned his Master's degree from the Georgia Institute of Technology and his Ph.D. from Texas A&M University at College Station, TX. Dr. Kim constructed a sophisticated pavement performance forecasting model using statistical methods in collaboration with Dr. James Lai in Georgia Tech. The model he developed has become an integral part of the Georgia Pavement Management System. Dr. Sung-Hee Kim accomplished the validation of the anisotropic modeling of graded aggregate base and asphalt mixture using the finite element program and comparing these predicted responses to the measured values. His papers based on this work related to Mechanistic Empirical Pavement Design Guide (MEPDG) were published by the Transportation Research Board, ASCE, and International Journal of Pavement Engineering, etc. Dr. Kim is a licensed professional engineer in the states of Louisiana and Georgia covering a broad range of geotechnical engineering, pavement design, pavement materials, and has industrial experiences in civil engineering research and pavement design projects. In his industrial experiences, Dr. Kim has successfully completed pavement management system (PMS) update, nondestructive testing data analysis, pavement structural design and rehabilitation recommendation for various highway pavements as well as airport pavements in Washington Dulles International Airport, Houston William P. Hobby Airport, Philadelphia International Airport, Port of Long Beach, Detroit International Airport, Louisville International Airport, Kentucky Samuels Field Airport, Kentucky Bowman Field Airport, El Paso International Airport, Long Island MacArthur Airport, and Cincinnati-Northern Kentucky International Airport.

Chih-Cheng Hung, Ph.D.: Chih-Cheng Hung is Professor in the School of Computing and Software Engineering at Southern Polytechnic State University, Marietta, GA. He attended the Soochow University in Taipei, Taiwan for his B.S. degree in Business/Applied Mathematics. He earned his M.S. and Ph.D. from the University of Alabama in Huntsville, AL in 1986 and 1990, respectively. He has worked extensively with imagery data and has developed software tools necessary for processing and analyzing the imagery data including Infrared images (U.S. Army), TM satellite images (multispectral for Intergraph Corporation in Huntsville, Alabama, USA), Polar UVI images (NASA, USA), face images, hyperspectral images, and medical images. He was with Intergraph Corporation, Huntsville, Alabama, USA where he designed and implemented imaging systems for image segmentation and automated analysis of multi-spectral images from 1990 to 1993. He was an associate professor in computer science at Alabama A&M University, Huntsville, AL from 1993 to 1999. He has been in collaboration with scientists from The University of Alabama in Huntsville (UAH) and Marshall Space Flight Center, NASA in Huntsville, APL John Hopkins University, Maryland. He has worked on Global Auroral images taken by Ultraviolet Imager (UVI), National Taichung University, Taichung, Taiwan, on hyperspectral image analysis and Huazhong University of Science and Technology, Wuhan, China, on medical image processing and analysis. Currently, he is working on facial recognition research with IDBIOMETRICS Inc. based in Atlanta, GA, USA. His research interests are in the areas of image processing and analysis, neural networks, computational intelligence, pattern recognition, and high-performance computing. He is a member of IEEE, ACM, and other associations. He serves as an Editorial Board Member for several journals.